

PB85-246981

Synfuel/Petrofuel
Conditioning and Delivery
Facility Operations Manual

Acurex Corp., Research Triangle Park, NC

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Jul 85



U.S. Department of Commerce
National Technical Information Service

NTIS

EPA/600/8-85/014
July 1985

SYNFUEL/PETROFUEL CONDITIONING AND DELIVERY FACILITY
OPERATIONS MANUAL

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Contract 68-02-3176
Work Assignment 40

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Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

TECHNICAL REPORT DATA (Please read instructions on the reverse before completing)		
1. REPORT NO. EPA/600/8-85/014	2.	3. RECIPIENT'S ACCESSION NO. PB85 246981/AS
4. TITLE AND SUBTITLE Synfuel/Petrofuel Conditioning and Delivery Facility Operations Manual		5. REPORT DATE July 1985
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) J. M. Kennedy, A. C. Minden, and J. E. MacQueen		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Acurex Corporation Energy and Environmental Division P. O. Box 13109 Research Triangle Park, North Carolina 27709		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-02-3176, Task 40
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Air and Energy Engineering Research Laboratory Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED User Manual; 5/82-9/84
		14. SPONSORING AGENCY CODE EPA/600/13
15. SUPPLEMENTARY NOTES AEERL project officer is Joseph A. McSorley, Mail Drop 65, 919/541-2920.		
16. ABSTRACT The report describes the Synfuel/Petrofuel Conditioning and Delivery Facility designed by Acurex Corporation for the U. S. EPA's Air and Energy Engineering Research Laboratory. The facility was designed to deliver synthetic fuels to five research facilities for comparative emissions testing with conventional petroleum based fuels. Capabilities of the facility include: heating and preblending of fuels delivered in 55-gal. drums; delivery of heated high viscosity fuels; delivery, mixing, and injection of a secondary light fuel along with a viscous synthetic fuel; and continuous fuel flow in a semi-automatic, unattended operational mode. Procedures are defined for the operation of all facility systems.		
17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Fuels	Stationary Sources	21D
Petroleum Products	Synthetic Fuels	11G
Fuel Conditioning	Petrofuels	10B
Coal		07D
Liquefaction		
18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 58
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

NOTICE

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ABSTRACT

This report describes the Synfuel/Petrofuel Conditioning and Delivery Facility designed by Acurex Corporation for the U.S. Environmental Protection Agency's Industrial Environmental Research Laboratory.* The facility was designed to delivery synthetic fuels to five research facilities for comparative emissions testing with conventional petroleum based fuels. Capabilities of the facility include: heating and preblending of fuels delivered in 55-gal drums; delivery of heated high viscosity fuels; delivery, mixing and injection of a secondary light fuel along with a viscous synthetic fuel; and continuous fuel flow in a semi-automatic, unattended operational mode. Procedures are defined for the operation of all facility systems.

This report was submitted in fulfillment of Contract 68-02-3176, Task 40 by Acurex Corporation under the sponsorship of the U. S. Environmental Protection Agency. This report covers a period from May, 1982 to March 1984 and work was completed as of September 1984.

(*) Now, the Air and Energy Engineering Research Laboratory.

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SECTION 1

INTRODUCTION

EPA's Industrial Environmental Research Laboratory at Research Triangle Park, NC is currently involved in a multiphased synfuel/petrofuel comparative combustion research project. The main objective of the project is to compare the emissions characteristics of shale- and coal-derived synthetic fuels with those of conventional petroleum based fuels. During the initial phase of the project, difficulties in the preparation and handling of the synthetic fuels led to excessive manpower requirements to supervise the fuel delivery system and ensure safe operating conditions.

These problems reflected the limitations in the existing equipment and overall facility for handling fuels supplied in 55 gal. drums, specifically relating to drum maneuvering and heating, and fuel conditioning and delivery. Routine handling of the drums is necessary due to project fuel requirements, and, in most cases, further required by the limited availability of synthetic fuel supplies in larger than drum size quantities.

In addressing these problems, IERL-RTP has installed a separate facility near the combustion test facilities for handling and conditioning the drums of test fuels. The facility and appurtenant equipment was designed specifically for routine handling of drums, preparation and on-line conditioning of fuels, and for semiautomatic instrumented delivery of fuels to the various test facilities in the IERL-RTP's combustion research laboratory.

As part of the design task, a preliminary design was prepared and serves as the basis for Section 2 of this report. Section 2 discusses the design requirements and constraints imposed by the test program objectives, the properties of the test fuels, and the combustion facilities' operational parameters.

Section 3 includes an overview of the system design and a description of the equipment installed. Section 4 discusses the system's operating procedures and Section 5 discusses maintenance procedures.

SECTION 2

FACILITY DESIGN REQUIREMENTS

The basic design features and requirements of the synfuel/petrofuel fuel-conditioning facility are:

- A portable (nonpermanent) building for efficient handling and preconditioning of liquid fuel contained in 55 gal.¹ drums.
- Easy access for maneuvering and locating the number of drums sufficient for each test utilizing a fork truck with drum lifting attachments.
- Internal instrumentation and equipment necessary to condition the fuel and transport it from the drums to the various test facilities, while monitoring fuel temperature, pressure, flowrate, etc.
- Appropriate controls to allow for continuous, uninterrupted flow of fuel in a semiautomatic unattended operational mode.
- Handling capability for a variety of petroleum and synthetic based fuels at a wide range of flowrates. In addition, the system should allow "at burner" fuel blending with methanol or other secondary blending fuel.
- Automatic safety equipment to accommodate possible system or operator malfunction. This includes overpressure and overheat limitation, fire extinguishing, ventilation and fuel spill containment.

2.1 CHAMP BUILDING

A portable building to house the fuel drums and related handling equipment had already been selected by EPA. The 10.5 x 16 ft building is

¹See Appendix B for English to metric conversions.

one previously used on an EPA ambient monitoring program and will henceforth be referred to as the "Champ building." The unit has two 42-in. wide doors, insulation, heating and air conditioning, and internal power hookup. These are features required by the design, although modifications were required to meet the demands of hazard protection. Dimensional and structural limitations of the Champ building limit the number of drums used, as well as the fuel conditioning and handling equipment design.

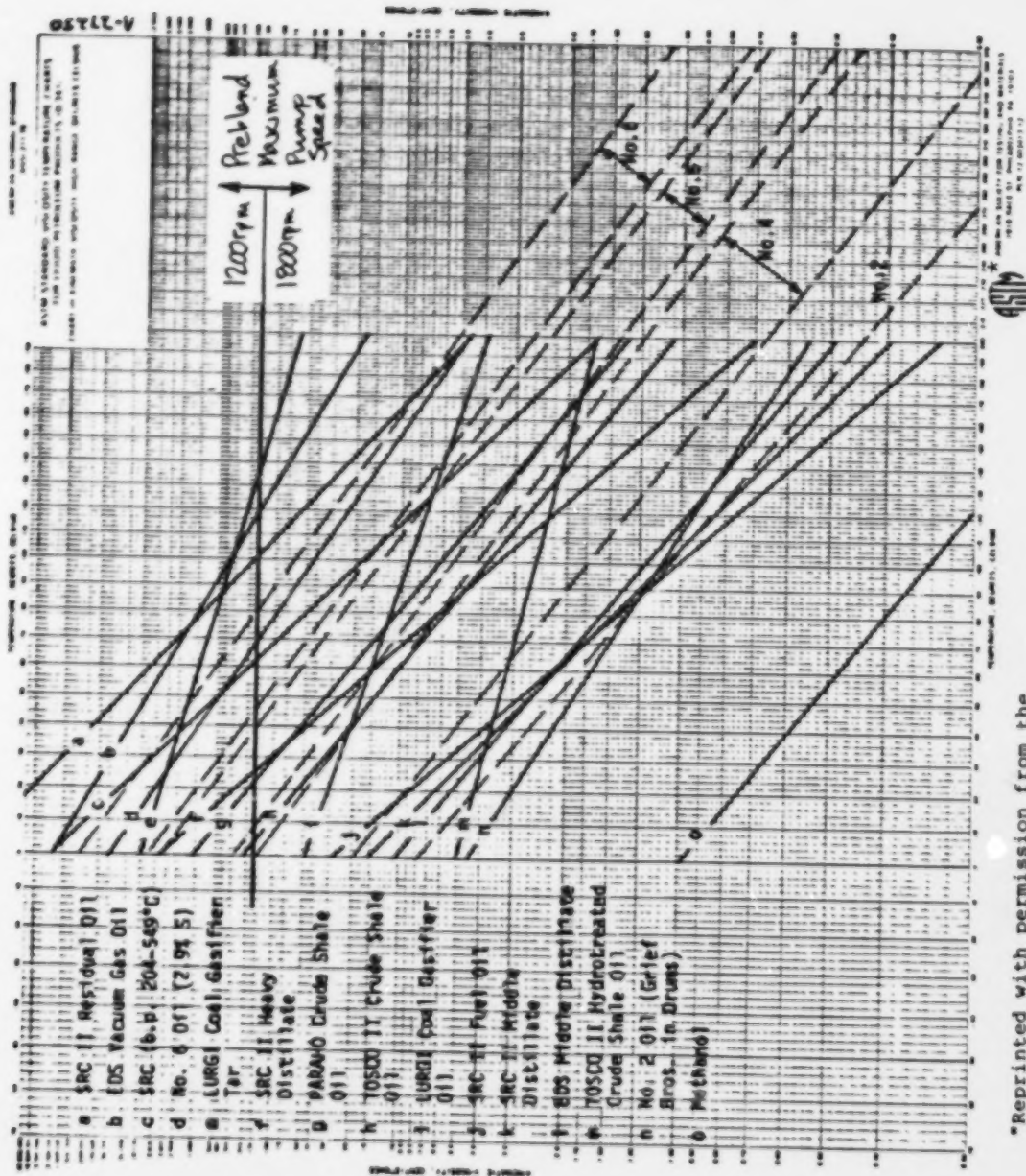
2.2 FUEL TYPES AND PROPERTIES

A wide variety of fuel types will be used in the comparative testing program for which the fuel-conditioning facility is to be used. Petroleum based fuels (from a light No. 2 domestic heating oil to a heavy No. 6 industrial fuel) and shale- and coal-derived synthetic fuels (ranging from light SRC and EDS distillates to SRC II Resid and Lurgi gasifier coal tar) are all considered candidate test fuels. Methanol is also included as both a fuel for blending and, in some cases, a primary fuel for combustion.

The properties of interest in designing the facility include:

- Specific gravity
- Viscosity
- Pour point
- Flash point
- Heating value

Of these properties, the most important is viscosity since it affects fuel flow. Figure 2-1 presents a chart of various synthetic fuels' kinematic viscosities plotted as a function of temperature. These are compared with the range of No. 2 through No. 6 petroleum fuels. The wide variations in the viscosity profiles of the various fuels including methanol indicate the need for system flexibility.



*Reprinted with permission from the
 Annual Book of ASTM Standards, Figure 1
 D 341. Copyright ASTM, 1916 Race Street
 Philadelphia, PA 19103. Pads of 50 charts
 are available direct from ASTM.

Figure 2-1 Synfuel and petrofuel viscosities as a function of temperature.

2.3 TEST FACILITY SUPPLY REQUIREMENTS

Although the basic fuel-conditioning facility has to be compatible with and capable of handling the full range of fuels indicated in Figure 2-1, the range of fuels supplied to each test facility does vary. Table 2-1 presents the firing rate, the range of fuels, and the maximum fuel flowrate anticipated for each of the test facilities. As noted, to achieve the maximum firing rates with pure methanol (except for the diesel engine where this is not likely to be possible), approximately twice the indicated fuel flowrate is required. This results in an overall fuel flowrate turndown ratio of 72:1.

2.4 FUEL BLENDING REQUIREMENTS

Test program objectives may require firing a blend of fuels at any one of the test facilities. The primary additive fuel will be methanol, although light oils may be used. Flexibility in fuel blending ratios and the unknown emulsification stability of the different possible mixtures require that the blending be done in-line, as close to the burner fuel delivery system as possible. The blending requirement therefore requires parallel supply lines to each combustor.

2.5 SYSTEM CONTROLS

Unattended operation of the fuel-conditioning facility is desired. This requires a control system that will provide a continuous supply of liquid fuel to the test facilities while monitoring and controlling supply temperature and pressure. In addition, shutdown of various system components should be automatically initiated in the event of excessive fluid temperatures or pressures due to equipment failures and/or operator errors.

2.6 SAFETY

The handling of combustible liquids at elevated pressures and temperatures requires that adequate safety precautions be taken to protect system operators

TABLE 2-1. SYN-FUEL/PETROFUEL COMPARATIVE TESTING PROGRAM
FUEL DELIVERY REQUIREMENT

Test Facility	Nominal Firing Rate (Btu/hr)	Fuel Types	Maximum Fuel Flowrate* (gal/hr)
North American Package Boiler	2.5×10^6	Methanol → EDS VG oil	17
DSU Furnace	4.5×10^6	Methanol → EDS VG oil	30
Diesel Engine	2.0×10^6	Methanol/NO. 2 Mix → No. 4 type	14
Gas Turbine Engine	5.0×10^6	Methanol → No. 4 type	36
Residential Furnace	150,000	Methanol and No. 2 type	1

* Maximum methanol flowrates are double fuel oil flowrates due to the lower heating value.

and the equipment itself from harm. These precautions can be subdivided into designing equipment (1) to prevent a system malfunction creating a hazardous operating condition, and (2) to control these conditions should they develop. The primary requirement for containing system malfunctions is that there should be two independent and identifiable mechanisms available to prevent any single point failure mode causing a hazardous condition. For example, excessive pressures are prevented by overpressure switches and pressure relief valves; or excessive temperatures are prevented by controllers and overtemp switches. Control of a hazardous condition once it occurs would be in the form of automatic fire extinguishing equipment, fire containment doors and walls, and liquid spill containment.

SECTION 3

FACILITY DESIGN

3.1 PIPING AND INSTRUMENTATION

The piping and instrumentation diagram for the facility is shown in Figure 3-1. The facility design is discussed here in terms of satisfying overall system requirements, while specific components are discussed in subsequent subsections.

To satisfy the methanol blending requirements, two parallel fuel supply circuits have been provided. The heat traced and insulated primary loop is designed for handling No. 2 through No. 6 fuel oils. The uninsulated secondary loop is designed primarily for use with methanol as both a blending additive and a separate fuel, but can be used for fuels up to No. 4, if desired.

The primary fuel loop can handle four drums of fuel with each drum externally heated to permit pumping fuels with high viscosities. Each drum is connected to the supply and return sides of the fuel oil recirculation loop with the flow path controlled by remotely operated solenoid valves. Once in the circulation loop, the fuel passes through a parallel set of strainers and is then pumped by a rotary gear pump to the test facility in use. All piping and other components in contact with the fuel in the primary loop are heat traced and insulated to maintain the desired pumping viscosity through the system. Flow meters are provided to measure supply line circulation flowrate and combustor fuel consumption rate.

The secondary fuel loop, designed mainly for methanol but also capable of handling light fuel oils, is similar to the primary loop, but is neither heat traced nor insulated.

In both the primary and secondary systems, a slight nitrogen pressure is established in the drums' headspace during operation to prevent combustible gas mixtures from forming when fuel is removed.

Due to the fuel blending requirement and the constraint that fuel mixing take place near the burners, parallel supply and return lines are provided from the primary and secondary loops to a portable mixing cart which is shared by the test facilities. Fuel delivery pressures, flowrates and blend ratio are adjusted and controlled at this point. The mixing station P&ID is presented in Figure 3-2. At each test facility a No. 2 oil hookup is provided for purging the burners after each test.

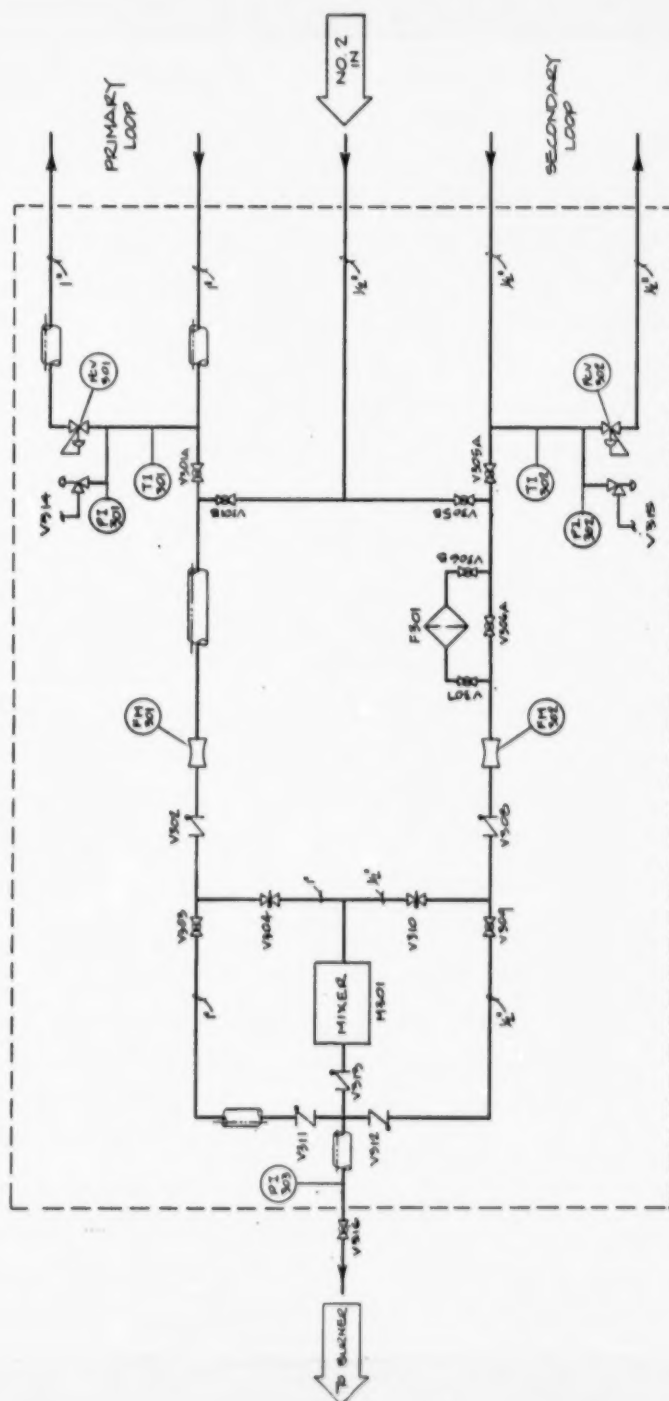
After each test, the system will be drained of the test oil, rinsed with No. 2 oil, and finally purged with nitrogen. A drain pump has been installed to accommodate this operation.

3.2 CHAMP BUILDING

The oil drums, pumps, heaters, and most meters and controls are located inside the Champ building described in Section 2. As shown in Figure 3-3, the building is located near the west wall outside of Wing G. This location was chosen for its proximity to the various test facilities in the combustion laboratory, and its accessibility in loading and unloading drums.

Drums, piping and other system components located in the Champ building are indicated on the P&ID, Figure 3-1. The physical arrangement of the equipment in the building is shown in Figure 3-4. Drums can be loaded into the building through either door, with each drum placed on a drum dolly and rolled into place. Four drums can be positioned near the east wall for the primary fuel loop and three near the west wall for the secondary fuel loop. Only these seven drums are initially connected to the pumping systems. If greater fuel capacity is required, additional drums may be substituted as the originals are emptied.

REVIEWS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	3-way valves replaced by 1-way	8-4-82	
	B	ADDED VIBIC	7-7-82	



QTY. REQD.		ITEM AND		CODE		PART NO.		DESCRIPTION	
-5B	-91								
UNLESS OTHERWISE SPECIFIED Dimensions are in inches Tolerances are as follows: FRACTIONS DECIMALS ANGLES 1/16 .0625 30° .0004 1/8 .1250 45° .0005 3/16 .1875 60° .0006 1/2 .5000 90° .0008 3/4 .7500 120° .0010 1 1.0000 150° .0012 1 1/2 1.5000 180° .0015 2 2.0000 210° .0018 3 3.0000 240° .0020 4 4.0000 270° .0025 5 5.0000 300° .0030 6 6.0000 330° .0035 7 7.0000 360° .0040 8 8.0000 390° .0045 9 9.0000 420° .0050 10 10.0000 450° .0055 11 11.0000 480° .0060 12 12.0000 510° .0065 13 13.0000 540° .0070 14 14.0000 570° .0075 15 15.0000 600° .0080 16 16.0000 630° .0085 17 17.0000 660° .0090 18 18.0000 690° .0095 19 19.0000 720° .0100 20 20.0000 750° .0105 21 21.0000 780° .0110 22 22.0000 810° .0115 23 23.0000 840° .0120 24 24.0000 870° .0125 25 25.0000 900° .0130 26 26.0000 930° .0135 27 27.0000 960° .0140 28 28.0000 990° .0145 29 29.0000 1020° .0150 30 30.0000 1050° .0155 31 31.0000 1080° .0160 32 32.0000 1110° .0165 33 33.0000 1140° .0170 34 34.0000 1170° .0175 35 35.0000 1200° .0180 36 36.0000 1230° .0185 37 37.0000 1260° .0190 38 38.0000 1290° .0195 39 39.0000 1320° .0200 40 40.0000 1350° .0205 41 41.0000 1380° .0210 42 42.0000 1410° .0215 43 43.0000 1440° .0220 44 44.0000 1470° .0225 45 45.0000 1500° .0230 46 46.0000 1530° .0235 47 47.0000 1560° .0240 48 48.0000 1590° .0245 49 49.0000 1620° .0250 50 50.0000 1650° .0255 51 51.0000 1680° .0260 52 52.0000 1710° .0265 53 53.0000 1740° .0270 54 54.0000 1770° .0275 55 55.0000 1800° .0280 56 56.0000 1830° .0285 57 57.0000 1860° .0290 58 58.0000 1890° .0295 59 59.0000 1920° .0300 60 60.0000 1950° .0305 61 61.0000 1980° .0310 62 62.0000 2010° .0315 63 63.0000 2040° .0320 64 64.0000 2070° .0325 65 65.0000 2100° .0330 66 66.0000 2130° .0335 67 67.0000 2160° .0340 68 68.0000 2190° .0345 69 69.0000 2220° .0350 70 70.0000 2250° .0355 71 71.0000 2280° .0360 72 72.0000 2310° .0365 73 73.0000 2340° .0370 74 74.0000 2370° .0375 75 75.0000 2400° .0380 76 76.0000 2430° .0385 77 77.0000 2460° .0390 78 78.0000 2490° .0395 79 79.0000 2520° .0400 80 80.0000 2550° .0405 81 81.0000 2580° .0410 82 82.0000 2610° .0415 83 83.0000 2640° .0420 84 84.0000 2670° .0425 85 85.0000 2700° .0430 86 86.0000 2730° .0435 87 87.0000 2760° .0440 88 88.0000 2790° .0445 89 89.0000 2820° .0450 90 90.0000 2850° .0455 91 91.0000 2880° .0460 92 92.0000 2910° .0465 93 93.0000 2940° .0470 94 94.0000 2970° .0475 95 95.0000 3000° .0480 96 96.0000 3030° .0485 97 97.0000 3060° .0490 98 98.0000 3090° .0495 99 99.0000 3120° .0500 100 100.0000 3150° .0505 101 101.0000 3180° .0510 102 102.0000 3210° .0515 103 103.0000 3240° .0520 104 104.0000 3270° .0525 105 105.0000 3300° .0530 106 106.0000 3330° .0535 107 107.0000 3360° .0540 108 108.0000 3390° .0545 109 109.0000 3420° .0550 110 110.0000 3450° .0555 111 111.0000 3480° .0560 112 112.0000 3510° .0565 113 113.0000 3540° .0570 114 114.0000 3570° .0575 115 115.0000 3600° .0580 116 116.0000 3630° .0585 117 117.0000 3660° .0590 118 118.0000 3690° .0595 119 119.0000 3720° .0600 120 120.0000 3750° .0605 121 121.0000 3780° .0610 122 122.0000 3810° .0615 123 123.0000 3840° .0620 124 124.0000 3870° .0625 125 125.0000 3900° .0630 126 126.0000 3930° .0635 127 127.0000 3960° .0640 128 128.0000 3990° .0645 129 129.0000 4020° .0650 130 130.0000 4050° .0655 131 131.0000 4080° .0660 132 132.0000 4110° .0665 133 133.0000 4140° .0670 134 134.0000 4170° .0675 135 135.0000 4200° .0680 136 136.0000 4230° .0685 137 137.0000 4260° .0690 138 138.0000 4290° .0									

Figure 3-2. P&ID-mixing station.

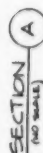
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Figure 3-3. Plot plan -- EPA Synfuel/Petrofuel Conditioning Facility

Piping, pumps, heaters, and the control system are arranged in the building to simplify system operation, allow interchanging of drums, and provide access to all system components. Some modification to the Champ building was required to accommodate this system. The portable building floor was reinforced and sealed to accommodate the added load of fuel oil drums and to provide containment in the event of a spill. All electrical components have been upgraded to NFPA Class I, Division II explosion proof rating. A ceiling exhaust vent was installed and the HVAC system air return blocked to prevent accumulation of flammable vapors by continuous purge/fresh air makeup.

3.3 HEATERS

The maximum tolerable viscosity for pumping the heavy fuel oils is approximately 10,000 SSU (2200 cSt). As indicated by the viscosity profiles of the various fuel types (Figure 2-1), heating of the most viscous fluid, SRC II Resid, to a minimum of 160°F (70°C) is required. The steady state design operating viscosity for the primary circulation loop is 1360 SSU (300 cSt) to lower piping and instrumentation pressure losses to a reasonable level. This requires a maximum operating temperature of 220°F (105°C) for the heaviest fuels.

Attaining and maintaining the fuel temperature is accomplished using external drum heaters, pipe heat tracing and appropriate insulation.

Each of the four drums in the primary loop is equipped with two wrap-around type Chromalox PFD-2305G thermostatically controlled heaters rated to 250°F. Tandem heaters, which can be used for fuel preheating, are also provided for the three secondary drums.

Pipe heat tracing is Chromalox Type DLR heating cable rated to a maximum operating temperature of 250°F. To prevent coking on heating elements and pipe internal surfaces, heating element watt densities were limited to 10 W/in.². The heat tracing is sized to maintain the maximum desired fluid temperature

(220°F). All piping is insulated to reduce losses to the surrounding environment.

3.4 PUMPS, PIPING, AND VALVES

System pumping requirements are based on combustor fuel consumption requirements, fuel supply loop circulation rates, and fuel properties including temperature and viscosity. A survey of pump types showed positive displacement rotary gear pumps met all system requirements and are used extensively throughout industry for fuel oil delivery systems.

The primary loop has two pumps available for fuel delivery. Both pumps are Viking rotary gear pumps with SCR speed controllers. The pumps have mechanical/Teflon seals and can be operated at a maximum temperature of 250°F and maximum discharge pressure of 250 psig. One pump (P101) has a nominal feed rate of 1.5 gpm and was designed to be the primary feed pump. The second pump (P104) was originally designed to be the preblend pump with a maximum capacity of 30 gpm. Experience with the system led to the determination that it is not practical to disconnect fuel-containing lines to switch pumps after preblending of hazardous fuels. It is within the capability of the control system to reduce the speed of the larger pump to levels required to deliver fuel to the Wing G facilities, making it unnecessary to open the piping. If tests are planned which do not require preblending, it is preferable to use the smaller pump. The controls for the larger pump were modified to shut down the pump in case of system overpressure.

Inline fuel blending is achieved by using both the primary and secondary circulation loops and a Chemineer Model 1/2 KMS 12 static mixer. Separate needle valves and flow meters on each system allow complete control of blend ratios. Pressure drop through the mixer should be limited to 5 psig for a mixture viscosity of 300 cp at a flow rate of 1.0 gpm. Figure 3-5 shows the

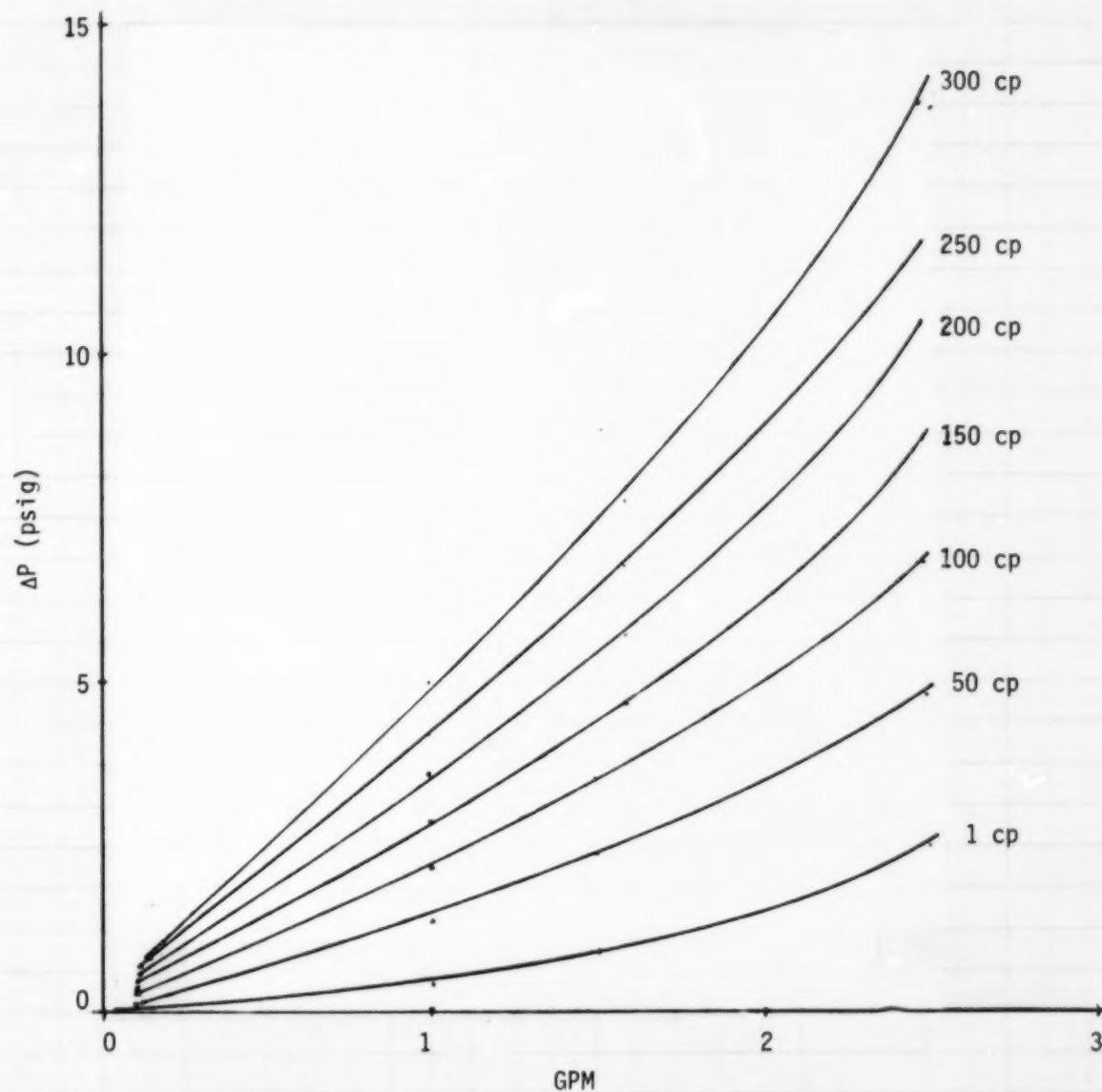


Figure 3-5. Manufacturer's estimate of pressure drop vs. flowrate
Model KMS 12 mixer.

manufacturer's supplied estimate of static mixer pressure drop as a function of fuel flow rate and mixture viscosity.

3.5 CONTROL SYSTEM AND INSTRUMENTATION

The basic purpose of the control system is to continually monitor the fuel level in the drums and to sequentially pump from each drum as the previous one is emptied. This is accomplished by means of solenoid valves operated by a relay logic system triggered by level switches in each of the fuel drums. An electrical schematic for the control system is presented in Figure 3-6a and 3-6b.

An additional purpose of the control system is to provide for safe operation of the fuel-conditioning facility. To achieve this, all of the heaters and pumps will be automatically shut down should an overpressure or overheat condition be detected. The drum heaters will also be switched off when each drum is emptied as a further precaution and energy saving feature of the system.

Instrumentation is provided to monitor fuel temperature, pressure, and flow-rates. Standard thermocouples and pressure gauges are used, although special Teflon diaphragm seals are required on the pressure gauges to minimize gauge fouling and fuel contamination.

Flow meters are installed in the main circulation supply lines and on the combustor fuel loop leaving the mixing cart. These monitor flow in the combustor fuel loops to ensure uniform combustor operation and monitor fuel blending ratios. Only gross fuel consumption rates can be measured by the existing instrumentation at each combustor. Figure 3-7 shows the control console with its instrumentation and controls located. This figure is reproduced in Appendix A for quick reference during operation.

3.6 SYSTEM SAFETY FEATURES

Pumping a variety of fuels with different combustion properties at elevated temperatures dictates that appropriate measures be taken to lessen the risk of

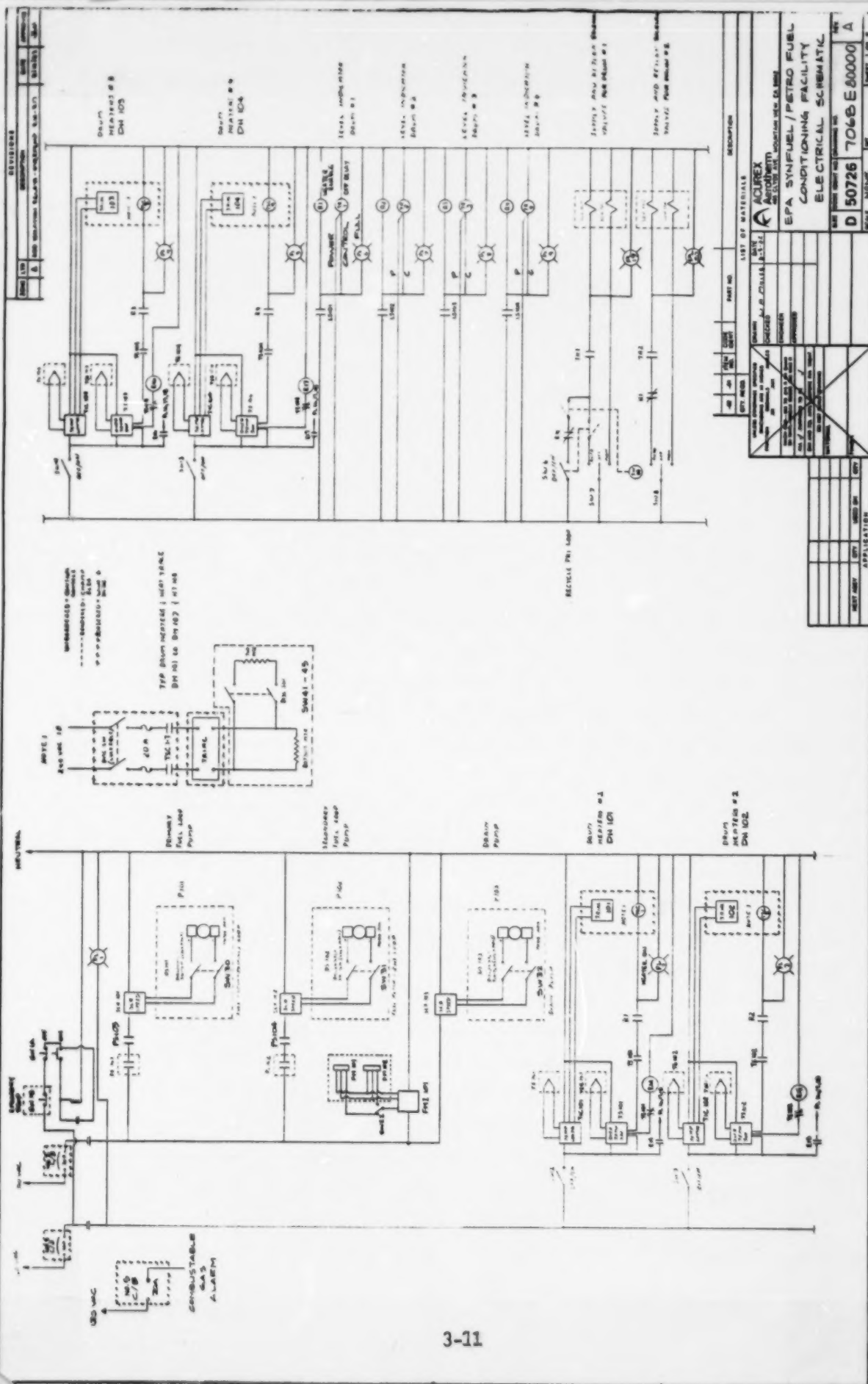


Figure 3-6a. Electrical schematic (pg. 1).

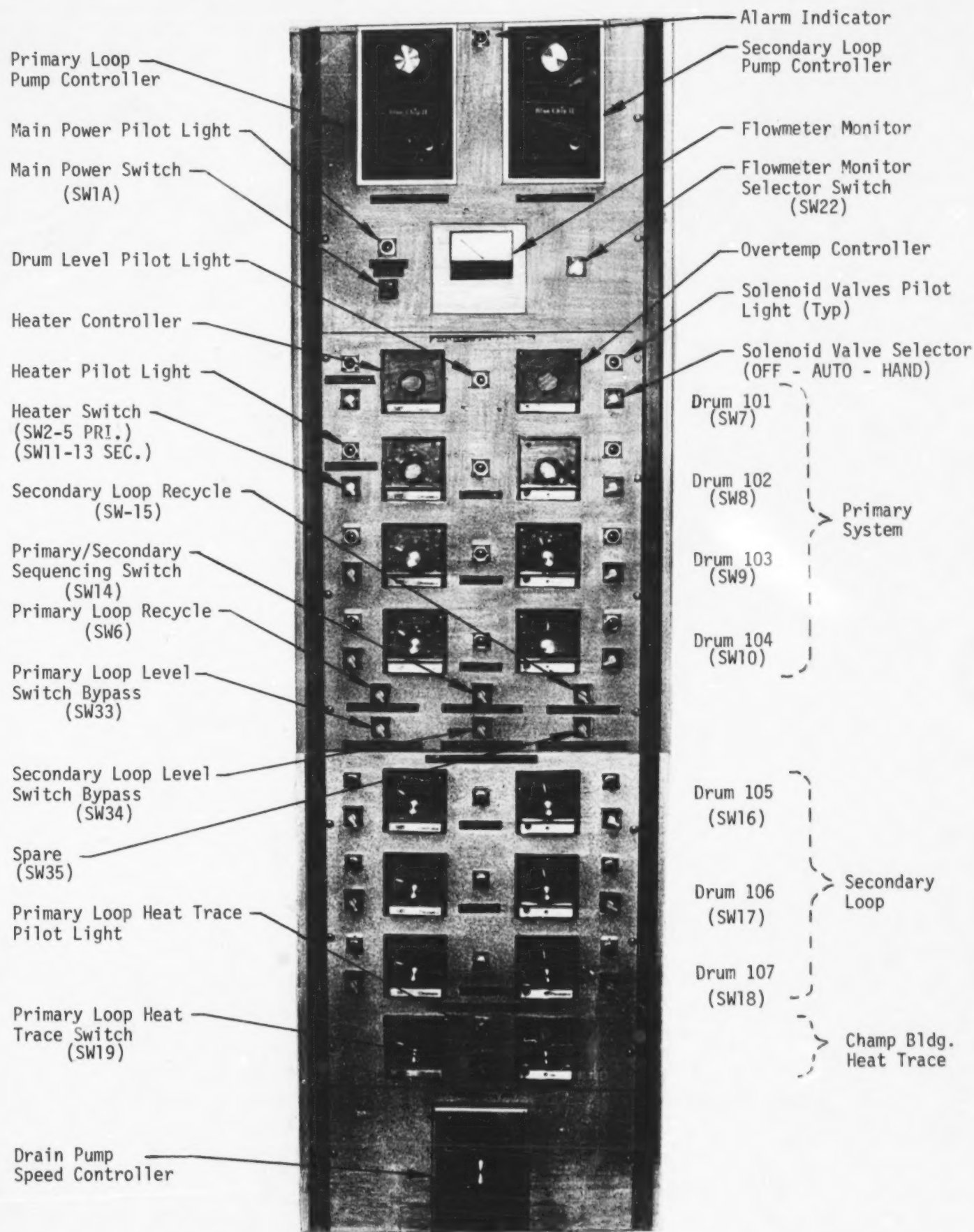


Figure 3-7. Control console.

personal injury or equipment damage in the event of either equipment malfunction or operator error. The principal safety considerations addressed in the design were:

- Protection against overheating the fuel.
- Protection against pressure buildup in the system.
- Prevention of accumulation of combustible vapors or explosive mixtures at various points in the system and protection against such occurrences.
- Spill protection.
- Adequate ventilation and climate control within the facility.

A number of safety subsystems have been installed to minimize the risks associated with fuel handling.

3.6.1 Overtemperature Control

Each pair of drum heaters (DH 101A&B - DH 107A&B) and each piping heat trace circuit is controlled to the desired temperature by a Chromalox model 3804 time proportioning controller. Drum heaters are enabled by a normally open relay operated by Magnetrol level detectors (LS 101-107). Overheat protection is provided by the coil for heater contactors (TSC 101-110) through normally open contacts in overtemperature switches (TS 101-110). Thermocouples for both the temperature controllers and overtemperature switches are paired to ensure simultaneous measurement.

3.6.2 Pressure Relief

Overpressure protection in both the primary and secondary recirculation loops is provided in the supply side by pressure switches (PS 101, PS 102) set at 50 psig which turn off the respective pumps (P 101, P 102) when activated. Further protection is provided by connecting the supply side to the return side through pressure relief valves (PRV 101, PRV 103) set at 45 psig. Protection in the return side of the loops is provided by a similar dual system of pressure switches (PS 103, PS 104) set at ~4.5 psig and connection of the return side to the drain loop

through pressure relief valves (PRV 102, PRV 104) set at 5 psig. Protection against overpressurizing the drums with the nitrogen purge system is provided by a 1 psig relief valve (PRV 401).

3.6.3 Nitrogen Purge

Provision has been made for purging all drum headspace and all process piping with nitrogen to eliminate the possibility of explosive mixtures in these areas. Further, the system is designed to maintain a constant <1 psig head pressure in the fuel drums as fuel is pumped out to test facilities. Normally, the drum headspace is purged during start-up (see Section 4.3.5, step 8) and then a constant head pressure is maintained, but continuous purge is not required. Distribution piping is purged with nitrogen following flushing with No. 2 fuel and is subsequently closed off, thus eliminating the possibility of explosive mixtures.

3.6.4 Combustible Gas Alarm

An MSA Model I501 combustible gas alarm with two detectors has been installed in the Champ building to monitor the environment for buildup of combustible vapors. One detector is installed just below the ceiling to provide protection against lighter-than-air vapors, while the second is located just above floor level to detect heavier-than-air components. The alarm provides a two-stage alerting system which sounds an alarm klaxon at the warning level (20% LEL), and turns the main control console and all associated equipment off at the alarm level (40% LEL). Restarting the system requires that the combustible vapor level be below the warning level and that a manual circuit breaker in the instrument be reset.

3.6.5 Automatic Fire Extinguishers

Total coverage of the Champ building is provided by six Halon 1301 automatic fire extinguishers which are thermally activated. All are installed just below the ceiling for greatest sensitivity.

3.6.6 Liquid Spill Containment

Containment of liquid fuel spills is provided by a 'bathtub' floor arrangement. A 6 in. sheet metal strip was installed around the perimeter of the inside walls at floor level. Dams were installed at the two entry/exits to provide continuity with the sheet metal. Joints in the flooring and at the corners were caulked using silicon rubber, and both floor and perimeter strip were painted with two coats of epoxy paint to seal the surfaces. A non-flammable container of STA-DRI absorption materials is provided for attending to small spills. In the event of a major spill, the 'bathtub' arrangement will contain the liquid until it is pumped out to a waste drum and properly disposed of.

3.6.7 Facility Ventilation/Climate Control

To ensure adequate ventilation, an 8-in. ceiling exhaust vent has been installed and several outside air vents have been provided at floor level. In addition, the Champ building integral HVAC system has been modified by sealing the air return and setting the fresh air damper for 100% makeup. These two modifications provide a continuous purge of fresh air out the top and bottom of the building to prevent the accumulation of flammable vapors.

3.6.8 Remote Emergency Stop/Panic Switch

An emergency-stop/panic switch (SW 1B) has been installed at the entrance to the Champ building to permit immediate shut off of all equipment from this location. This switch de-energizes the main power relay and thus turns off power to all systems. Once the emergency situation is corrected, the system must be restarted from the control console with the main power switch (SW 1A).

SECTION 4

FACILITY OPERATION

4.1 FUEL DRUM STATIONS

Identical fuel drum stations are provided at each of seven locations in the primary and secondary circulation loops of the fuel conditioning facility. These stations provide for hook-ups to each of the conditioning systems required for each drum. A typical fuel drum station (with equipment identification for the first drum station in the primary circulation loop) is shown in Figure 4-1. The systems in each station include:

- Fuel supply and return recirculation piping.
- Nitrogen purge inlet, exhaust, and pressure relief lines.
- Thermocouple extension leads for temperature control and overheat switch thermocouple probes.
- Fuel drum low-level switch.
- Drum heaters and insulation jackets.

Many of these systems are located in or share components with the drum head assemblies. They provide for all piping and instrumentation access to the fuel drums through standard 2-in. and 3/4-in. NPT bung holes. There are three separate assemblies, one for use during system preheat, and the other two when fuel circulation is required.

4.1.1 Preheat Drum Head Assembly

The preheat drum head assembly is used while the fuel is being preheated from ambient conditions to the desired pumping temperature, and provides for thermocouple and pressure relief access. The procedure for installing this assembly is:

1. Thread the assembly into the 2 in. NPT bung hole using pipe thread sealant.



Figure 4-1. Typical fuel drum station (equipment identification for D101 primary loop).

2. Insert 12 in. long thermocouples until they reach the fuel surface, hand tighten Teflon ferrules.
3. Connect thermocouple extension jacks.
4. Connect nitrogen purge exhaust and relief lines.
5. Close exhaust line shut-off valves V406-V409 and V413-V415.

Once the fuel is preheated to the desired operating temperature this assembly can be removed and the standard drum head assembly can be installed as described below.

4.1.2 Fuel Circulation Drum Head Assemblies

The fuel circulation drum head assemblies (Figure 4-2) are used for fuel circulation and level control instrumentation.

The larger assembly, shown on the left of the drawing, provides suction and return piping, thermocouple fittings, and a nitrogen purge supply line. This assembly is designed to be connected to suction and discharge piping manifolds for any of the primary, secondary or preblend circulation loops.

The procedure for installing this assembly is:

1. Thread the circulation assembly into the 2 in. NPT bung hole using pipe thread sealant.
2. Connect suction and return piping to piping manifolds.
3. Connect thermocouple extension leads to probe plugs.
- 4a. Primary/secondary: connect nitrogen purge supply tubing and open valves (primary: V402-V405, secondary: V410-V412) (refer to Figure 3-1).
- 4b. Preblend: connect nitrogen purge pressure relief tubing and close exhaust valves (primary: V406-V409, secondary: V413-V415).

The second assembly consists of the capacitance level switch probe and nitrogen purge pressure relief and exhaust system. This system should be installed when automatic sequencing of drums is required or whenever drums are

heated. During operation of the alternate preblend system, use of level switches is not required. Installation procedure for this system is as follows:

1. Thread nipple/union half assembly into 3/4 in. NPT bung hole using pipe thread sealant.
2. Slide level switch probe assembly into drum and tighten pipe union.
3. Connect nitrogen purge pressure relief tubing and close exhaust valves (primary: V406-V409, secondary: V413-V415).

4.1.3 Fuel Drum Temperature Control

The fuel drums and primary circulation loop are provided with temperature control equipment consisting of Type J thermocouples, temperature controllers, and overtemperature switches, heating elements, and insulation.

Two drum heaters (220 VAC silicone rubber coated resistive heating bands) are located at each fuel drum station. They are wired in parallel, with the upper drum heater switched to allow greater flexibility in matching electrical load to heating capacity during initial warm-up and temperature maintenance conditions. Two in. thick, silicone rubber coated, fiberglass insulation jackets are provided to minimize heat loss from the fuel drums.

Drum Heater Assembly:

1. Install preheat drum head assembly (see Section 4.1.1 and note below).
2. Strap on upper and lower drum heater bands with power cord interconnection boxes located along plane formed by bung holes and drum centerline.
3. Place two halves of drum insulation jacket together around drum and lace together.

4. During fuel drum preheat, close contacts ("start") on drum heater disconnect switches (primary: SW41-45, secondary: SW46-48) located in the Champ building behind primary and secondary circulation loop pumps (P101 and P102) to enable the operation of the upper heater.
5. Turn on primary and/or secondary circulation loop level switch by-pass switches (SW33 and SW34) located on the control panel as required.
6. Adjust setpoint temperatures on temperature controllers (TIC 101-TIC107) and overheat switches (TS101-TS107), turn on drum heater control power switches (SW2-SW5 and SW11-SW13), and reset overheat switches (TS101-TS107), if necessary.
7. When fuel drum operating temperature is reached, open contacts ("stop") on drum heater disconnect switches in the Champ building.
8. Remove preheat drum head assembly and install fuel circulation drum head assembly (see Section 4.1.2).
9. Connect primary circulation loop piping as required.
10. Install level switch probe and nitrogen purge pressure relief and exhaust system.
11. Turn off primary and secondary circulation loop level switch bypass switches (SW33 and SW34).

NOTE: The fuel circulation drum head assembly and level switch probe assembly can be installed at any time the fuel is fluid enough to insert piping and probes. It is advisable to do this as early in the preheat operation as possible to minimize release of volatile fuel components.

4.2 FUEL PREBLENDING

To ensure uniformity of fuel properties in separate drums during a test, preblending capability has been incorporated into the fuel conditioning facility. The pumping capacity of this system is sufficient to provide a

volumetric exchange rate of at least 6 volumes per hour for most fuels. Ten volumetric exchanges is considered sufficient to properly homogenize fuel between drums. A totalizing flowmeter is installed in each drum suction line to verify sufficient mixing.

The system has the following major features:

- Recirculate fuel within up to four drums.
- Mate with existing drum head assemblies.
- Variable speed pump drive with pumping rate determined from performance curves of positive displacement rotary gear pump.
- Operation at ambient or elevated temperatures.
- Capability to flush and drain system piping with house No. 2 oil.
- Flowmeter for each drum to ensure balanced blending.

Preblending of the primary loop can take place while facilities are being operated on the secondary system.

4.2.1 Preblend Fuel Temperature Selection

The first step in the preblend operation is to select an operating temperature. The large primary loop pump, a Viking heavy-duty rotary gear pump, is designed to pump at up to 1800 rpm for fuels with viscosities less than 750 SSU (165 cSt), and up to 1200 rpm for fuels with viscosities greater than 750 SSU. Figure 2-1 shows how fuel viscosity (as a function of temperature) relates to this constraint on the pumping speed. Another constraint is that the net positive suction head (NPSH) into the pump cannot exceed 10 in. Hg for volatile fuels and 15 in. Hg for non-volatile fuels. A final constraint is that the fuel cannot be heated to a temperature greater than its flash point for safety reasons. Table 4-1 summarizes these constraints. Once it has been determined that fuel heating is required, the procedures outlined in Section 4.1.3 can be followed as appropriate.

Table 4-1. PREBLEND PUMPING SPEED AND TEMPERATURE CONSTRAINTS

Pump Speed:	for > 750 SSU < 1200 rpm
	for < 750 SSU < 1800 rpm
NET Positive Suction Head:	for volatile fuels NPSH < 10 in. Hg
	for non-volatile fuels NPSH < 15 in. Hg
Flash Point:	$T_{\text{fuel}} < T_{\text{flash point}}$

4.2.2 Primary Preblend Start-Up

Once heating requirements are established and preheating accomplished, preblend the fuel, utilizing the following procedures:

1. If using the smaller primary recirculation pump (P 101), disconnect it from primary loop piping and connect the larger pump (P 104) using preblend suction and discharge 'S' connectors.
2. Connect drums to suction and discharge sides of primary recirculation loop (right side of Champ building) and install level switches according to Section 4.1.2.
3. Open manual suction and return ball valves (V102, V104, V106, V108, V113, V115, V117, V119 located in insulated legs to drums) for drums being used.
4. Open all drum isolation valves (V103, V105, V107, V114, V116, V118) for drums being used.
5. Open nitrogen purge exhaust valves (V406-V409) and supply valves (V401-V405) for drums being used. Open the cylinder valve (V416) and adjust the pressure regulator PCV 401 to 5 psi and regulator PCV 402 to 0.5 psi or until slight gas flow can be detected. Allow the drum(s) headspace to purge for approximately 5 minutes, then close all exhaust valves. Check to ensure that no further nitrogen flow is detected and adjust the pressure regulator to achieve this situation.
6. Open preblend recirculation valve V111B and ensure that facility supply valve V111A is closed.
7. Set solenoid valve switches for drums being used (SW7-10 on right side of control panel) to HAND.

8. Open valves V145A, V109A, V110A, and V147A in primary loop around pump.
9. Turn the preblend pump disconnect (SW 36) inside the Champ building adjacent to P104 to ON.
10. In the Parajust control panel located outside the Champ building, adjust the speed control potentiometer to 25% and depress the momentary START switch to start the larger pump.
11. Adjust the potentiometer for maximum pump rate achievable without overpressurizing pressure switches PS 101, and PS 103 or pressure relief valve PRV 102.
12. Adjust drum suction valves V102, V104, V106, and V108 so that flows (as measured by flowmeters FM 110-113) are balanced. This will ensure that none of the drums are being short-circuited.
13. Allow preblending to continue until the desired number of volumetric exchanges has been achieved:

$$\text{Number of volume exchanges} = \frac{(\text{minutes})(\% \text{ f.s. pump})(30 \text{ gpm})}{(\text{number of drums})(55 \text{ gals/drum})}$$

An approximation of volume exchanges can also be made by utilizing the flowmeter totalized readings.

4.2.3 Primary Preblend ShutDown

Once the desired degree of preblending has been accomplished, the system may be shutdown simply by reversing the sequence of the start-up procedure except for steps (5) and (2). The larger pump and the 'S' connectors should be flushed thoroughly with No. 2 fuel oil following use if P104 is to be disconnected. The preferable operational mode is to use P104 as the primary loop circulation pump after preblending. The speed control potentiometer should be adjusted to <20% of full scale. Appendix A outlines the procedures for preblending in checklist form.

4.3 FUEL CIRCULATION AND DELIVERY SYSTEM

The fuel circulation and delivery system consists of two parallel piping circuits. The primary circulation loop is designed to handle light to heavy fuels that may require heating to facilitate pumping. The secondary circulation loop is designed to handle light fuels and methanol (as a possible blending fuel) that do not require heating. The primary circulation loop has four fuel drum stations while the secondary has three fuel drum stations. Parallel supply and return piping from both circulation loops provides for fuel distribution to any of three stations servicing four combustion test facilities in G-Wing High-Bay:

- North American Package Boiler (2.5×10^6 Btu/hr).
- DSU Furnace (4.5×10^6 Btu/hr).
- Gas Turbine (5.0×10^6 Btu/hr).
- Diesel Engine (2.0×10^6 Btu/hr).

4.3.1 Fuel Circulation Temperature Selection

Selection of an appropriate temperature setpoint for fuel circulation is based on several considerations. Safe system operation requires fuel temperature below its flash point to minimize the hazard in the event of accidental spill. However, many of the heavier fuels must be heated to reduce piping pressure losses. A maximum fuel viscosity of 300 cs is recommended to extend the service life of the Brooks flow meters used in the system. Figure 2-1 shows how viscosity for a variety of prospective fuels varies as a function of temperature in light of this constraint. These various parameters define a minimum recirculation temperature for many of the synthetic based fuels well above ambient conditions. Although both recirculation loops have the capability for heating the fuel in the drums, the secondary loop is not designed for recirculating heated fuel since the piping lacks heat tracing and insulation.

Therefore, more viscous fuels need to be recirculated using the primary loop while all other fuels may be recirculated using either loop.

4.3.2 Drum Station and Distribution Piping Selection

The fuel firing rate and test duration will determine the number of fuel drums needed for a specific test. Table 4-2 estimates these requirements for the different test facilities and fuel types. The primary recirculation loop consists of four drum stations, while the secondary loop consists of three drum stations, representing, respectively, approximately 180 and 135 gallons of available fuel. Selection of drum stations and associated distribution piping will be determined by a combination of fuel consumption and temperature control requirements.

4.3.3 Manual/Automatic Drum Sequencing

For flexibility in operation, both manual and automatic drum sequencing are provided for in primary and secondary recirculation loops. This allows unattended operation of the system with uninterrupted fuel supply. Available operation modes and characteristics include:

1. Manual - permits selection of any individual drum from either recirculation loop or operation on No. 2 house oil supply. Only solenoid valves associated with the individual drum are actuated and level switch control is bypassed hence drum may be pumped 'dry'. On control panel, set desired mode selector switches (SW 7-10, 16-18) to 'HAND' or, for operation using #2 house oil supply, leave all switches in the OFF position.
2. Auto - permits selection of any number of drums within either recirculation loop. Level switch control of solenoid valves sequences from one drum to the next activated drum when level setpoint is reached preventing pumping the drum 'dry'. Set mode selector switches for drums in use (SW 7-10 and 16-18) to 'AUTO' on control panel.

TABLE 4-2. FUEL DRUM REQUIREMENTS FOR 8-HOUR TESTING

	Pipe Size (in)	Total Pipe Length (ft)	Piping Volume (gal)	Number of Drums Required ^a			
				Methanol (gpm)	No. 2 Oil (gpm)	No. 4 Oil (gpm)	No. 6 Oil (gpm)
Residential Furnace ^b	1/2	210	3.3	0.4 (0.04)	0.2 (0.02)	0.2 (0.02)	--- (---)
Diesel Engine ^b	1/2	150	2.3	4.9 (0.5)	2.2 (0.2)	2.1 (0.2)	--- (---)
Gas Turbine ^b	1/2	170	2.7	13.1 (1.4)	5.6 (0.6)	5.5 (0.6)	--- (---)
N.A. Package Boiler ^c	1	140	6.2	6.9 (0.7)	3.0 (0.3)	2.9 (0.3)	2.8 (0.3)
DSU Furnace ^c	1	210	9.4	11.3 (1.2)	5.2 (0.5)	5.1 (0.5)	4.8 (0.5)

^a Assuming 6" of fuel (10 gal) remain in each fuel drum due to level switch operational constraints

^b Methanol and No. 2 through No. 4 fuel oils only

^c All fuels

3. Primary Loop Recycle - permits continuous sequencing within the primary recirculation loop; (i.e., 1, 2, 3, 4, 1, 2, 3, 4 ...). As one drum is emptied, the next drum is sequenced. The empty drums may be replaced with full ones as long as the drum just emptied is left unfilled. For example, drum 1 cannot be refilled while pumping from drum 2, but may be refilled or replaced when pumping from drum 3 and 4, thus allowing for extended testing or high firing rates. On the control panel, set all primary loop mode selector switches (SW 7-10) to AUTO and primary loop recycle switch (SW 6) to ON. Primary loop recycle switch must be left off while pumping from drum 101 if system is to be started with four full drums.
4. Secondary Loop Recycle - permits secondary loop continuous sequencing as described for primary loop. On the control panel, set all secondary loop mode selector switches (SW 16-18) to AUTO and switch SECONDARY LOOP RECYCLE switch (SW 15) to ON after drum 5 is emptied.
5. Primary/Secondary Loop Sequencing - Allows uninterrupted seven drum sequence operation with both primary and secondary loop drums when viscosity and heating parameters permit. Set primary and secondary loop solenoid switches (SW7-10, 16-18) to AUTO and Primary/Secondary loop switch (SW14) to ON after the first drum is emptied (or startup with drum 7 empty). Valves 145B, 146, 147B, and 148, which separate primary and secondary loops must be opened for this operation. Some fluctuation in recirculation loop flow and pressure may change when the switch from primary to secondary systems is made.

4.3.4 Fuel Feed Cart

The portable fuel mixing cart provides a means for connecting either or both of the fuel circulation loops to the various test facilities while maintaining desired temperature and delivery pressure. Additionally, Brooks positive

feedrate to the user facility. A Brooks frequency to analog converter, shared by the two flowmeters, is provided to monitor flowrate. An additional feature of the mixing cart is the provision for dynamic blending of two fuels immediately prior to burning. Blending is accomplished by a Chemineer model KMS 12 mixer (M301) and relative preparations of the primary and secondary fuels controlled by needle valves (V304,V310). Adjustment of blend ratio is monitored by comparison of flowrates in the primary and secondary circulation loops. To operate using only primary recirculation loop fuel, open user facility supply/return line valves and mixing cart primary loop valves V301A, V303, and V316. To operate using only secondary recirculation loop fuel, open user facility supply/return line valves and mixing cart secondary loop valves V305A, V306B, V307, V309, and V316. For dynamic blending operation, open user facility supply/return valves and mixing cart valves V301A, V305A, V306B, V307, V316, and adjust needle valves V304 and V310 to achieve desired blend ratio.

4.3.5 Start-Up

Once the desired operating parameters have been selected and required preheating and preblending accomplished, the system is ready for operation. To start up the system use the following sequence:

1. Control Console Main Power switch (SW 1A) should be ON.
2. Mixing cart 120V power plug and 240V heat trace plugs should be connected to receptacles provided at the test facility.
3. Drum heat switches on control panel (SW 2-5, 11-13), temperature controller disconnect/ fuse/contactors assemblies on control room wall (TSC 101-107), and drumheater disconnects in Champ building (SW 41-47) should be ON as desired and drum heat temperature controllers (TIC 101-107) and overtemperature protection (TS 101-107) on control panel set to desired setpoint.

4. Piping heat-trace switches (SW 19-21) located on main, DSU, and NAB control consoles, and temperature controller disconnect/fuse/contactors assemblies (TSC 108-110), located on control room wall should be ON as desired and temperature controllers (TIC 108, 201, 203) and overtemperature protection (TS108, 202, 204) set to desired setpoint.
5. Verify that all sequencing switches are in "OFF" position.
6. Open manual suction and return ball valves (V102, V104, V106, V108, V113, V115, V117, V119, V123, V125, V127, V135, V137, V139) associated with and adjacent to solenoid valves for drums being used.
7. Open drum isolation (supply and return manifolds) valves (V103, V105, V107, V114, V116, V118, V124, V126, V136, V138) for drums being used.
8. Open nitrogen purge supply valves (V401-V405, V410-V412) and exhaust valves (V406-V409, V413-V415) for drums being used. Open the nitrogen cylinder valve (V416) and adjust pressure regulator PCV401 to ~5 psi and pressure regulator PCV402 until slight gas flow can be detected (<1 psi). Allow the drum(s) headspace to purge for approximately 5 minutes, then close all exhaust valves. Check to ensure that no further nitrogen flow is detected and adjust the pressure regulator to achieve this situation.
9. For Primary Loop operation only, open valves V109A, V110A (109B, 110B), V111A, V145A, V147A and mixing cart valves V301A, V303, and V316.
10. For Secondary Loop operation only, open valves V128, V129, V130A, V132A, V133 and mixing cart valves V305A, V306B, V307, V309, and V316.
11. For simultaneous Primary and Secondary Loop operation with dynamic blending, open valves as specified in steps 9 and 10 above and mixing cart valves V301A, V305A, V306B, V307, V316.

12. For Primary/Secondary Loop sequencing operation, open valves V145B, V146, V147B, and V148, separating primary and secondary loops, in addition to those specified in step 9 (primary loop operation).
13. Set the Analog Flow monitor selector switch (SW22), located on the control panel, to the desired position: Primary or Secondary.
14. For Primary Loop and Primary and Secondary sequencing operation turn the Parajust speed controller (SCR104) for the large primary loop pump (P104) to "ON" and adjust speed to ~20% (in panel on outside of Champ building). If the smaller pump (P101) is being used, turn the Minark speed controller, located on the control panel, (SCR 101) to ON and adjust the control to 75%. A red lamp should indicate that the appropriate controller is powered. An absence of such indication may be caused by either pressure switch (PS 101, PS 103) being open and may be remedied by resetting the switch(es). Go to the Champ station and turn the Primary Loop pump disconnect switch (SW34 for P104, SW30 for P101) to ON and watch pump discharge pressure guage (PI 103) and Return Line pressure guage (P104) for indications of an overpressure situation (>20 psig or >5 psig, respectively). If Pump 104 is being used, reduce the pressure or circulation flow by adjusting the pump bypass valve V152. In the event an overpressure situation develops, turn the primary loop pump disconnect switch (SW34 or SW30) in Champ building to OFF and locate and remedy the cause before proceeding. If pressures are within limits, adjust controller to set pump rate so that pressure gauge P301 indicates 14-15 psig.

15. For Secondary Loop operation follow directions in step 14 using speed controller SCR 102 on control panel, pump P102, pressure switches PS 102 and PS 104, disconnect switch SW 31 (in Champ building), and pressure gauges PI 104, PI 107, and PI 302.
16. For operation using 'House' No. 2 oil supply, open supply valves V101B, V122, V124, V126, V128, V129, V130A, V132A, V133, V153 and secondary loop mixing cart valves V305A, V306B, V307, V309, and V316. This allows the oil to bypass the secondary pump (P102) and uses the 'House' oil pump as the driving force. When operating in this mode it is important that the return valve at the user facility be closed to prevent an overpressure situation in the Champ return piping.

4.3.6 Shutdown

To shut down the system when operating in any mode, simply reverse the start-up procedures described in Section 4.3.5. Appendix A contains a checklist for facility start-up procedures.

4.3.7 Drain and Flush

Once the system has been shut down it is important to drain all fuel from the piping; flush the piping thoroughly with No. 2 fuel oil and purge the system with nitrogen in order to prevent damage to (or plugging of) the piping. To accomplish this task, use the following procedures:

1. Turn solenoid valve switches (SW 7-10, 16-18) for drums utilized to HAND.
2. Ensure that manual ball valves for drums used and isolation valves for the recirculation loop(s) used are all open.
3. Open bleeder valves V230-V237, as required, and allow fuel to drain back into the drums.

4. Turn all solenoid valve switches to OFF.
5. Open valve V142A to drain pump (P103).
6. Turn Drain Pump Minark speed controller (SCR 103) to ON and set controller to 75%.
7. Turn the Drain Pump disconnect (SW 32) to ON allowing pump to empty return line(s).
8. Open supply/return connector valve(s) (V143,V144) as required to allow pump to empty the supply lines.
9. Turn Drain Pump disconnect (SW 32) to OFF.
10. Close supply/return connector valve(s) (V143,V144).
11. Close bleeder valves V230-V237.
12. Close all manual ball valves specified in Section 4.3.5 step 6.
13. Open No. 2 oil supply valves V101 A&B and V122 to allow the system to fill with No. 2 fuel oil from 'house' supply. Some flow into the waste drum should be expected and observed.
14. Close No. 2 oil supply valves (V101 A&B and V122).
15. If remaining oil in drum(s) is not to be used for further testing, repeat steps 1-10, above. If remaining oil is to be used for further testing, repeat steps 3 and 5-10, above.
16. Open nitrogen purge valve(s) V147, V148 and cylinder valve to fill all piping with N₂.
17. Close bleeder valves V230-V237.
18. Close N₂ cylinder valve and V147, V148.
19. Turn Minark speed controller (SCR 103) OFF.
20. Close valve V142A.

This completes the drain and flush of system piping.

SECTION 5.0

MAINTENANCE

Very little maintenance is required of the equipment in the facility since the principal component is piping. However, a few items do require routine attention:

1. Following each test, in-line strainers and/or filters should be removed and cleaned or replaced as required.
2. Function of the MSA combustible gas alarm should be checked at the beginning of each test and calibration checked at least every 90 days.
3. The Halon 1301 fire extinguishers should be weighed and weights recorded every 6 months.
4. Pressure relief valves should be checked and adjusted every 6 months.
5. Pumps should be checked for seal wear and tolerances reset in accordance with manufacturer's recommendations annually or as required.

APPENDIX A
SYNFUELS OPERATIONS CHECKLIST

SYNFUELS OPERATIONS CHECKLIST

PREBLEND

1. Preheat drums if necessary.
2. Verify large pump (P104) is installed in primary loop.
3. Install drum head assemblies and level switches.
4. Open drum supply and return manual ball valves.
5. Open drum isolation manual ball valves (on supply and return manifold).
6. Establish nitrogen purge for drums in use.
7. Close facility supply valve (V-111A) and open preblend recirculation valve (V111B).
8. Set drum shut-off solenoid valve switches to "HAND".
9. Verify all valves from drums to pump and back to drums are open.
10. Turn on pump speed control and adjust speed to maintain proper loop pressures.
11. Adjust manual drum suction valves to balance flows from each drum.
12. Continue until desired number of exchanges are completed.

START-UP

1. Turn Main Control Power "ON" (SW 1A).
2. Verify drum heater and heat trace (Champ Building and mixing cart) power and controller settings.
3. Verify sequencing switches are "OFF".
4. Open drum supply and return manual ball valves.
5. Open drum isolation manual ball valves (on supply and return manifolds).
6. Establish nitrogen purge for drums in use.
7. Verify all valves between drums and facility are open for loop(s) in use - (primary/secondary pumping loops and mixing cart loops).
8. Set drum shut-off solenoid valve switches (SW 7-10) to "AUTO".
9. For primary/secondary loop sequencing, open loop interconnection valves.
10. Set analog flow monitor switch to desired position: primary or secondary.
11. Turn on the appropriate pump speed controller and adjust speed to indicate 15 psi in loop supply-side pressure.
12. After first barrel is emptied, turn proper sequencing switch to "ON".
13. If using "House" No. 2 oil, open No. 2 supply valves and pump bypass valve on secondary loop. Do not operate secondary pump. Close return valve at facility to prevent return loop overpressure.

SHUTDOWN

Reverse start-up procedures.

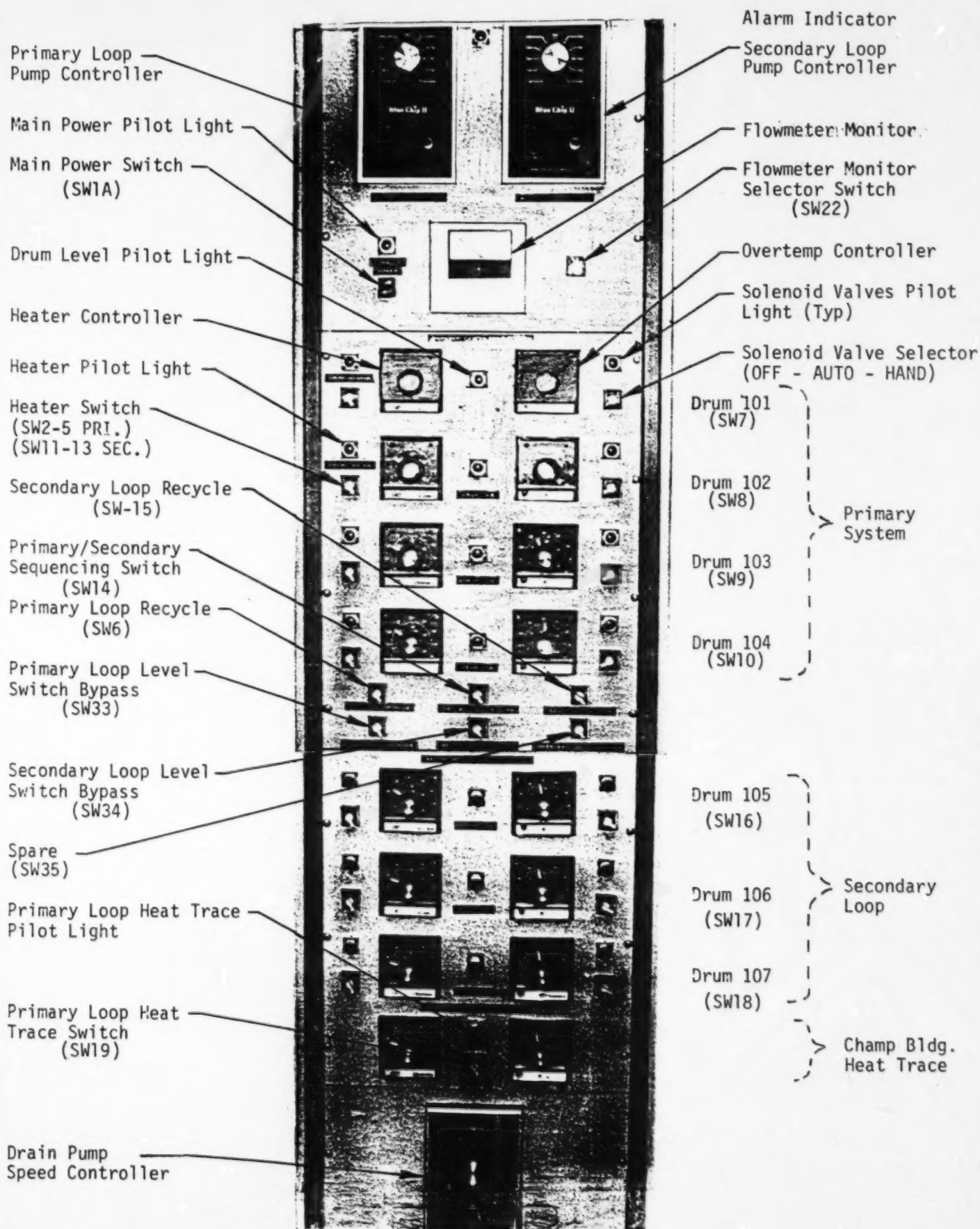


Figure A-1 Control Console

Appendix B
CONVERSION TABLE

English Unit	Multiplication Factor	Metric Unit
Btu	0.2520	kg-cal
Btu/hr		kg-cal/hr
°F	5/9 - 17.78	°C
ft.	0.3048	m.
gal.	3.785	l.
gpm	0.227	m ³ /hr
gph	3.875 x 10 ⁻³	m ³ /hr
in.	2.54	cm.
in. Hg	345.3	kg/m ²
PSI	3.390 x 10 ⁻²	kg/m ³
SSU	0.2157	centistokes
Watts/in. ²	2.22 x 10 ⁻³	kg-cal/min
		cm ²